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(54) Apparatus controlled by data from consumable parts with incorporated memory devices

(57) A printing system (10) includes a replaceable cartridge (20) for housing a supply (26) of consumable marking media. The cartridge (20) includes a cartridge memory (28) for recording printing system-related parameters, including marking media parameters. A replaceable printing device (12), such as an ink jet head, includes a printhead memory (16) for recording printing device-related parameters. A processor (34,35) is coupled to the cartridge memory (28), the printhead memory (16) and is responsive to parameters read from both memories (28,16) to derive printing system function control values that are dependent upon one or more marking media parameters from the cartridge memory (28) and one or more parameters from the printhead memory (16). The processor (34,35) is thus able (in the case of an ink jet printing system (10)) to determine a current ink supply value from a cumulative usage value stored on the cartridge memory (28) and a drop volume parameter stored on the printhead memory (16). Further, a drop volume parameter stored on the printhead memory (16) can be adjusted to accommodate a media type sensed by a media sensor (30).

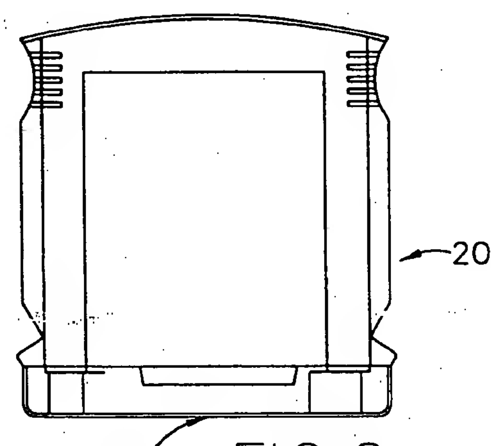

FIG. 2

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Description

FIELD OF THE INVENTION

This invention relates to apparatus that employs replaceable, consumable parts and, more particularly, to consumable parts which include integral memory for storing usage, calibration and other data that is used by a controlling processor to operate the apparatus.

BACKGROUND OF THE INVENTION

Substantially, all present-day copiers, printers, plotters, etc., include a controlling microprocessor which requires input calibration data to assure high quality production of documents. Since most such apparatus allows user-replacement of consumable items, various techniques have been developed to enable entry of usage, calibration and other data.

In regards to ink jet printers, it has been proposed that print heads incorporate a parameter memory for storage of operating parameters such as: drop generator driver frequency, ink pressure and drop charging values (see "Storage of Operating Parameters in Memory Integral with Print Head", Lonis, Xerox Disclosure Journal, Volume 8, No. 6, November/December 1983, page 503). U. S. Patent 5,138,344 to Ujita, entitled "Ink Jet Apparatus and Ink Jet Cartridge Therefor", indicates that an ink-containing replaceable cartridge can be provided with an integral information device (i.e., a resistor element, magnetic medium, bar code, integrated circuit or ROM), for storage of information relating to control parameters for the ink jet printer.

U. S. Patent 5,365,312 to Hillmann et al., entitled "Arrangement for Printer Equipment Monitoring Reservoirs that Contain Printing Medium", describes the use of memory devices integral with the ink reservoirs which store ink consumption data (for use by a coupled ink jet printer) . European patent EP 0 720 916, entitled "Ink Supply Identification System for a Printer" describes the use of an ink supply having an integral EEPROM which is utilized to store data regarding the identity of the ink supply and its fill level.

The prior art further teaches the use of consumable parts with integral memory for use in electrophotographic printers. In U. S. Patent 5,021,828 to Yamaguchi et al., entitled "Copying Apparatus having a Consumable Part", a toner cartridge is disclosed which includes a memory for storing data regarding to the state of consumption of toner in the cartridge. U. S. Patents 4,961,088 to Gilliland et al.; 4,803,521 to Honda; 5,184,181 to Kurando et al.; and 5,272,503 to LeSueur et al. all describe various replaceable toner cartridges for use in electrophotographic printers. Each cartridge incorporates a memory device for storing parameter data regarding the cartridge.

Ink jet and laser printers have, in recent years, become more sophisticated in their operational and control functionalities. For instance, many such printers exhibit resolutions at levels of 600 dots per inch (dpi), double the previous printer generation resolution of 300 dpi. At such higher resolutions, misadjustments which were not visible at lower resolution levels become highly visible. Further, such printers are now being applied to generation of grey-scale images on media, requiring precise density and tonal control of the deposited ink/toner.

Thus, while it has been known that changes in functionality of various elements of a printer interact to affect print quality, many of those interactions could be ignored in the lower resolution printers. However, with performance improvements of new printer designs, such interactions must now be taken into account and compensated to assure high quality print documents.

Accordingly, it is an object of this invention to provide a print apparatus with an improved capability for adjustment of printer control functions.

It is another object of this invention to provide an improved printer control system which is able to update control parameters that are dependent upon current printer performance parameters contained on plural consumable parts.

It is yet another object of this invention to provide an improved ink jet printer which incorporates real time print control functions that are responsive to parameters read from plural consumable parts.

SUMMARY OF THE INVENTION

A printer includes a replaceable cartridge for housing a supply of consumable marking media. The cartridge includes a cartridge memory for recording printer-related parameters, including marking media parameters. A replaceable printing device, such as an ink jet head, includes a printhead memory for recording printing device-related parameters. A processor is coupled to the cartridge memory, the printhead memory and is responsive to parameters read from both memories to derive printer function control values that are dependent upon one or more marking media parameters from the cartridge memory and one or more parameters from the printhead memory. The processor is thus able (in the case of an ink jet printer) to determine a current ink supply value from a cumulative usage value stored on the cartridge memory and a drop volume parameter stored on the printhead memory. Further, a drop volume parameter

stored on the printhead memory can be adjusted to accommodate a media type sensed by a media sensor.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1a is a perspective view of an ink jet printer (with cover removed), which incorporates the invention.

Fig. 1b is a block diagram of components of the ink jet Printer of Fig 1a.

Fig. 2 is a frontal view of an ink-containing cartridge usable in the ink jet printer shown in Fig. 1.

Fig. 3 is a side view of the ink cartridge of Fig. 2.

Fig. 4 is a schematic sectional view of the ink cartridge of a Fig. 2.

Fig. 4a is an expanded view of Fig. 4, showing details of a cartridge memory installed on the ink cartridge.

Fig. 5 is a perspective view of an ink jet printhead employed with the invention hereof.

Fig. 6 is a schematic diagram indicating certain data stored in the cartridge memory contained on the ink cartridge of Fig. 2 and the printhead memory stored on the printhead of Fig. 5, and illustrating the usage of such data in deciding printer control values.

Fig. 7 is a schematic of a display used in the system of Fig. 1, illustrating a "gas gauge" to indicate the ink supply level in the ink cartridge of Fig. 2.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1a illustrates a perspective view of an ink jet printer 1 incorporating the invention. A tray 2 holds a supply of input paper or other print media. When a printing operation is initiated, a sheet of paper is fed into printer 1 and is then brought around in a U direction towards an output tray 3. The sheet is stopped in a print zone 4 and a scanning carriage 5, containing plural, removable color printheads 6, is scanned across the sheet for printing a swath of ink thereon. The process repeats until the entire sheet has been printed, at which point, it is ejected onto output tray 3.

Printheads 6 are, respectively, fluidically coupled to four removable ink cartridges 7 holding Cyan, Magenta, Yellow and Black inks. Since black ink tends to be depleted most rapidly, the black ink cartridge has a larger capacity than the other cartridges. As will be understood from the description which follows, each printhead and ink cartridge is provided with an integral memory device which stores data that is used by printer 1 to control its printing operations.

Fig. 1b illustrates a block diagram of elements of the ink jet printer of Fig. 1a. Ink jet printer 1 includes a pluggable printhead 12 which includes a print element 14 and an integrally mounted printhead memory 16. Printhead 12 is pluggably removable from printer 1 via interconnects 18. An ink cartridge 20 is also pluggably removable from printer 1 via electrical interconnect 22 and fluidic interconnect 24. Ink cartridge 20 includes an ink reservoir 26 and an integral cartridge memory 28. The contents of memories 16 and 28 will be considered in detail below and, as will be understood, are instrumental in enabling real time control of ink jet printer 1 to produce high quality printed media.

A media detector 30 is positioned to scan an incoming media sheet 32 and determine from characteristics thereof, the specific type of media sheet which is being presented to printhead 12 for printing. Media sheet 32 may carry indicia that is only visible to media detector 30 (e.g., via an infra-red scan) or other indicia indicative of the media type.

Ink cartridge 20, printhead 12 and media detector 30 are interconnected to a microprocessor 34 which includes both electronics and firmware for the control of the various printer sub-assemblies. A print control procedure 35, which may be incorporated in the printer driver, causes the reading of data from cartridge memory 28 and printhead memory 16 and adjusts printer control parameters in accordance with parameter re-calculations based upon the data accessed from both memories.

A host processor 36 is connected to microprocessor 34 and includes a central processing unit (CPU) 38 and a software printer driver 40. A monitor 41 is connected to host processor 36 and is used to display various messages that are indicative of the state of ink jet printer 1.

Fig. 2 illustrates a frontal view of ink cartridge 20 and Fig. 3, a side view thereof. Ink cartridge 20 is pluggable into a receptacle (not shown) in ink jet printer 1 and includes both a fluidic interconnection and an electrical interconnection, both of which are accessible through bottom surface 42. Fig. 4 shows a section of ink cartridge 20 and illustrates the positioning of ink reservoir 26, a fluidic connector 44 and an electrical connector 46. Electrical connector 46 enables interconnection to a cartridge memory chip 20.

An expanded view of connector 46 and memory chip 20 are shown in Fig. 4a, with connector 46 making contact to a mating connector in the receptacle within ink jet printer 1 when ink jet cartridge 20 is pluggably inserted thereinto.

Fig. 5 is a perspective view of printhead 12 and illustrates the placement of printhead memory 16 thereon. A plurality of contacts 48 enable pluggable interconnection to printhead memory 16 as well as various electrical elements within printhead 12. Printhead 12 is a known, thermally-actuated ink jet printhead, with a print element (including an orifice plate) positioned at surface 14. Behind each orifice is an ink chamber with a heater resistor. A thermal sense resistor is positioned on the printhead and detects the temperature of the semiconductor substrate on which the heater resistors are positioned. A fluidic interconnect 50 connects ink cartridge 12, via ink flow path 24 (see Fig. 1), to ink res-

ervoir 26 in ink cartridge 20. When printhead 12 is plugged into a receptacle (not shown) within ink jet printer 1, contacts 48 make electrical connection to a mating connector in the printer and fluidic interconnect 50 automatically mates to ink flow path 24 to enable a flow of ink thereto.

As indicated above, cartridge memory 28 and printhead memory 16 enable microprocessor 34 to calculate control values which enable printer 1 to maintain high quality print media output. Data from media detector 30 is also employed for certain aspects of print media quality enhancement. To accomplish control of printer parameters, each of memories 16 and 28 includes both factory-written data and printer-recorded data. While not complete, the following is a list of data values stored within the aforesaid memories:

<u>Cartridge memory 16</u>

Factory-written data:

Product tag

Supply size

Color map coefficients
Ink colorimetry
Color code
Dry time coefficient
Printer driver revision number
Printer driver revision parameters
Re-order part number
Manufacture day
Manufacture year
Freshness date
Ink shelf life
Serial number
Print mode coefficients
Outgas rate data for ink

Printer written data:

Coarse count
Fine count
First insertion date
Last usage date
In-use time

Printhead memory 16

Factory recorded data:

Product tag
Drop volume measurement
Drop volume coefficients
Manufacture year
Manufacture day
Freshness date
Temperature sense resistor calibration data
Printhead alignment coefficients
Firing energy parameters
Print mode coefficients
Re-order part number
Driver version number

```
Printer-recorded data:
     Number of drops fired
     First insertion date
     Last usage date
     In-use time
     Number of pages printed.
```

As will be hereafter understood, print control procedure 35 makes use of the above-indicated parameters stored in memories 16 and 28 to control the operation and print quality of media output from ink jet printer 1. In a number of instances, data from both memories 16 and 28 are utilized to arrive at an improved control parameter. Further, the ability to periodically replace memories 16 and 28, as their host carriers (e.g., printhead 12 or ink cartridge 20) are replaced, enables the manufacturer to provide updated parameters, on a continuing basis, to customers who already have installed printers.

Turning to Fig. 6, subprocedures incorporated into print control procedure 35 will be described which utilize data from both printhead memory 16 and cartridge memory 28 and, in some cases, an input from media sensor 30. Before describing the subprocedures, it is worthwhile to consider certain details of the data stored in printhead memory 16 and cartridge memory 28.

A fine count value 52 stored in cartridge memory 28 is an 8-bit (for example) re-writable value, with each bit corresponding to 1/256 of 12.5% of the total supply volume of ink cartridge 20. To calculate when to "flip" a fine count bit value, print control procedure 35 reads both a drop volume parameter 54 (encoded on printhead memory 16) and an ink supply volume value 56 (encoded on cartridge memory 28). Print control procedure 35 then calculates how many drops are required too cause one fine count bit flip (i.e., an amount equal to 1/256 of 12.5% of the total supply volume). Then. by counting input signals fed to the heater resistors (as indicative of the cumulative number of emitted ink drops), print control procedure 35 knows when to increment the value in fine count value 52.

When ink cartridge 20 is first inserted, print control procedure 35 reads the manufacture day/year data 58 to determine the age of ink cartridge 20. Thereafter, the value of fine count entry 52 is adjusted to take into account evaporation assumptions.

A coarse count value 60 in cartridge memory 28 is incremented each time 12.5% of the ink in ink cartridge 20 is consumed. Coarse count value 60 is incremented each time fine count value 52 "rolls over". As will be hereafter understood, fine count value 52 and coarse count value 60 are both utilized to determine an amount of remaining ink in ink cartridge 20.

As indicated in Fig. 6, a drop usage calculation subprocedure 70 employs a number of values stored on both cartridge memory 28 and printhead memory 16 to calculate an amount of ink remaining in ink cartridge 20. Thus, drop usage calculation subprocedure 70 reads drop volume parameter 54 from printhead memory 16 and ink supply size parameter 56 from ink cartridge memory 28. Further, inputs from thermal sense resistors 76 (associated with print element 14 in Fig. 1) are also input to drop usage calculation subprocedure 70. From the drop volume parameter and thermal sense resistor inputs, the total volume of drops emitted are calculated and, using supply size parameter 56, subprocedure 70 calculates the remaining amount of ink available in cartridge 28. Upon arriving at such a calculated value, fine count value 52 is incremented to reflect the current ink usage state and, if a "roll-over" of the count is sensed, coarse count value 60 is also incremented. These calculations occur as printing takes place, with fine count value 52 and coarse count value 60 being incremented to reflect the volume of ink ejected by printhead 12. As drop usage calculation subprocedure 70 arrives at new values for fine count value 52 and coarse count value 60, such values are accordingly rewritten into cartridge memory 28 via data line 74.

Because ink supply cartridge sizes will vary, both drop volume parameter 54 and initial supply size parameter 56 are used in the calculation.

A drop volume parameter update subprocedure 75 is periodically run to account for changes in drop volume which occur as printhead 12 ages. Drop volume parameter update subprocedure 74 initially accesses drop volume parameter 54 from printhead memory 16. It then employs cumulative usage data to estimate the state of the printhead. That cumulative usage value is calculated by use of fine count value 52, coarse count value 60 from a current ink cartridge 20 and previous fine and coarse count values from now-replaced ink cartridges. That data is accumulated on printhead memory 16 in the form of a cumulative "number of drops fired" value 76. An algorithm for re-calculation of drop volume uses the following expressions:

$$Vcalc = Vmeas + \Delta Vtrans + \Delta Vtime + \Delta V\#drops + \Delta V(T) + \Delta V(f)$$

$$\Delta Vtime = k1t + k2t^2 + ...$$

$$\Delta V\#drops = c1N + c2N^2 + ...$$

$$\Delta V(T) = b1T + b2T^2 + ...$$

$$\Delta V(f) = d1f + d2f^2 + ...$$

where:

Vcalc = calculated drop volume
Vmeas = drop volume measured in the factory.
ΔVtrans = transient drop volume change (from surface wetting or burn-in).
ΔVtime = effect of time (long term) on drop volume
k1, k2, ... = constants
t = time elapsed since printhead was manufactured

Note: the constants are characterized and encoded at the printhead factory; the time t is calculated by the printer by comparing the computer clock to the date code on the printhead.

ΔV#drops = effect of firing on drop volume (long term -- build up on resistor)
c1,c2, ...= constants
N = number of drops fired since printhead was manufactured
ΔV(T) = effect of temperature
b1, b2, ... = constants
T = printhead temperature. It is calculated from a formula that relates the temperature to the TSR (thermal sense resistor) output; the TSR is monitored by the system to infer head temperature.
ΔV(f) = Effect of firing frequency
d1, d2, ... = constants

Note: Vtrans, k1, k2, d1, d2, c1, c2, b1, b2 are recorded at the factory; t is recorded on the printhead memory chip by the printer (by comparing a computer clock to the date code recorded on the ink cartridge memory); and N is recorded on the cartridge memory chip by the printer.

As the usage of printhead 12 increases, drop volume parameter update subprocedure 74 alters the drop volume parameter to track changes in the drop volume (e.g., as a result of ink build-up in the ink chambers and other factors). That drop volume parameter may then be rewritten to printhead memory 16 via data line 80.

In order to provide the user with an indication of remaining ink in ink cartridge 20, drop usage calculations subprocedure 70 provides an output value to host processor 36 which implements a display procedure to cause monitor 40 to exhibit a "gas gauge" which is shown on monitor 41 in Fig. 7. Monitor 41 includes a gas gauge representation 73 in the lower left corner thereof. As the remaining ink quantity in ink cartridge 20 reduces, the indication of gas gauge 73 is altered accordingly.

A further subprocedure is periodically run each time a new media type is sensed by media sensor 30. As indicated above, media sensor 30 is enabled to detect a specific media type by invisible or visible indicia imprinted on the media and to provide a media type value to a dot density calculation subprocedure 82. In response, dot density calculation subprocedure 82 reads drop volume parameter 54 from printhead memory 16 and ink colorimetry parameter 84 from ink cartridge memory 28. Utilizing those two parameters, dot density calculation subprocedure 82 then calculates adjustments required for changes in dot density to achieve a correct hue and intensity on the sensed media type.

It should be understood that the foregoing description is only illustrative of the invention. Various alternatives and modifications can be devised by those skilled in the art without departing from the invention. While the above invention has been described in the context of an ink jet printer, those skilled in the art will realize that it is equally applicable to other printer/copier arrangements which employ replaceable units and wherein control procedures are dependent upon parameters read from multiple such replaceable units. Accordingly, the present invention is intended to embrace all such alternatives, modifications and variances which fall within the scope of the appended claims.

Claims

1. A printing system (10) comprising:

   replaceable cartridge means (20) for housing a supply (26) of consumable marking media and including cartridge memory means (28) for recording printer-related parameters, including marking media parameters;

   replaceable print means (12) for producing marks on a print media and including printhead memory means (16) for recording print means-related parameters;

   processor means (34, 35) coupled to said cartridge memory means (28) and said printhead memory means (16) and responsive to parameters read from both said cartridge memory means (28) and said printhead memory means (16) for deriving a printer function control value that is dependent upon at least a marking media parameter from said cartridge memory means (28) and a print means-related parameter from said printhead memory means (16).

2. The printing system (10) as recited in claim 1, wherein said replaceable cartridge means (20) is an ink reservoir cartridge that is pluggably insertable into said printing system (10) and said cartridge memory means (28) forms an integral part of said cartridge (20) and makes electrical connection to said printing system (10) upon insertion of said cartridge (20).

3. The printing system (10) as recited in claim 2, wherein said printing system control function value is a number of ink drops that are fired per count of an ink volume counting means.

4. The printing system (10) as recited in claim 2, wherein said replaceable print means (12) is an ink jet printhead (12) that is pluggably insertable into said printing system (10) and said printhead memory means (16) forms an integral part of said ink jet printhead (12) and makes electrical connection to said printing system (10) upon insertion of said ink jet print head (12).

5. The printing system (10) as recited in claim 4, further comprising:-

   sense means (76) coupled to said ink jet printhead (12) for producing signals indicative of mark production by said ink jet printhead (12), said processor means (34,35) further employing data derived from said signals to arrive at said printing system control function value.

6. A replaceable ink cartridge (20) for an ink jet printing system (10), the printing system (10) including a plurality of printheads (6) of different colors for ejecting droplets of ink on media, each printhead (12) including a printhead memory element (16) having printhead factory parameters stored thereon, the printing system (10) having a processor means (34,35) for controlling printing system function, the processor means (34,35) coupling with the printhead memory element (16) so that the processor means (34,35) has access to the printhead factory parameters, the printing system (10) including an ink station (7) for supplying ink to the printhead (12), the ink station (7) including a plurality of receptacles corresponding to the plurality of printheads, the replaceable ink cartridge (20) comprising:

   a cartridge body having an ink reservoir (26) therein, the cartridge body adapted to be releasably mounted to one of the plurality of receptacles in said ink jet printing system (10);

   a discharge port (44) in fluid communication with the ink reservoir (26), the discharge port (44) establishing fluid communication with a fluid inlet in one of the plurality of receptacles when the cartridge body is releasably mounted to one of the plurality of receptacles to thereby enable ink to flow out of the discharge port (44) and to an associated printhead (12) when the cartridge body is releasably mounted to one of the plurality of receptacles; and

   an ink cartridge memory element (28) adapted to electrically couple to the processor means (34,35) when the cartridge body is releasably mounted to one of the plurality of receptacles, the ink cartridge memory element (16) thereby providing ink cartridge factory parameters to the processor means (34,35); and
   wherein, in order to carry out a printing operation where ink is transferred from the ink reservoir (26) through the discharge port (44) and to the printhead (12), certain factory-inserted parameters stored in the ink cartridge

memory element (28) are transmitted from the ink cartridge memory element (28) to the processor means (34,35) so that the processor means (34,35) combines at least one ink cartridge factory-inserted parameter and at least one printhead factory-inserted parameter to derive a usage control parameter for the printhead (12).

7. The replaceable ink supply (20) of claim 6, wherein the ink reservoir (26) has a deliverable volume of ink and wherein the at least one ink cartridge factory parameter includes a value corresponding to the deliverable volume of ink.

8. The replaceable ink supply (20) of claim 6, wherein the at least one printhead factory parameter includes a value corresponding to the drop volume of the printhead (12).

9. The replaceable ink supply (20) of claim 6, wherein the ink reservoir (26) has a usage life, and the processor means (34,35) periodically calculates the usage control parameter during a usage life of the ink reservoir (26) to provide an updated usage value, the processor means (34,35) periodically writing the-updated usage value to the ink cartridge memory element (28).

10. The replaceable ink supply (20) of claim 9, wherein the processor means (34,35) reads the usage control parameter from the ink cartridge memory element (28), the processor means (34,35) combines at least one ink cartridge factory parameter, at least one printhead factory parameter, and the usage control parameter to calculate the updated usage control parameter.

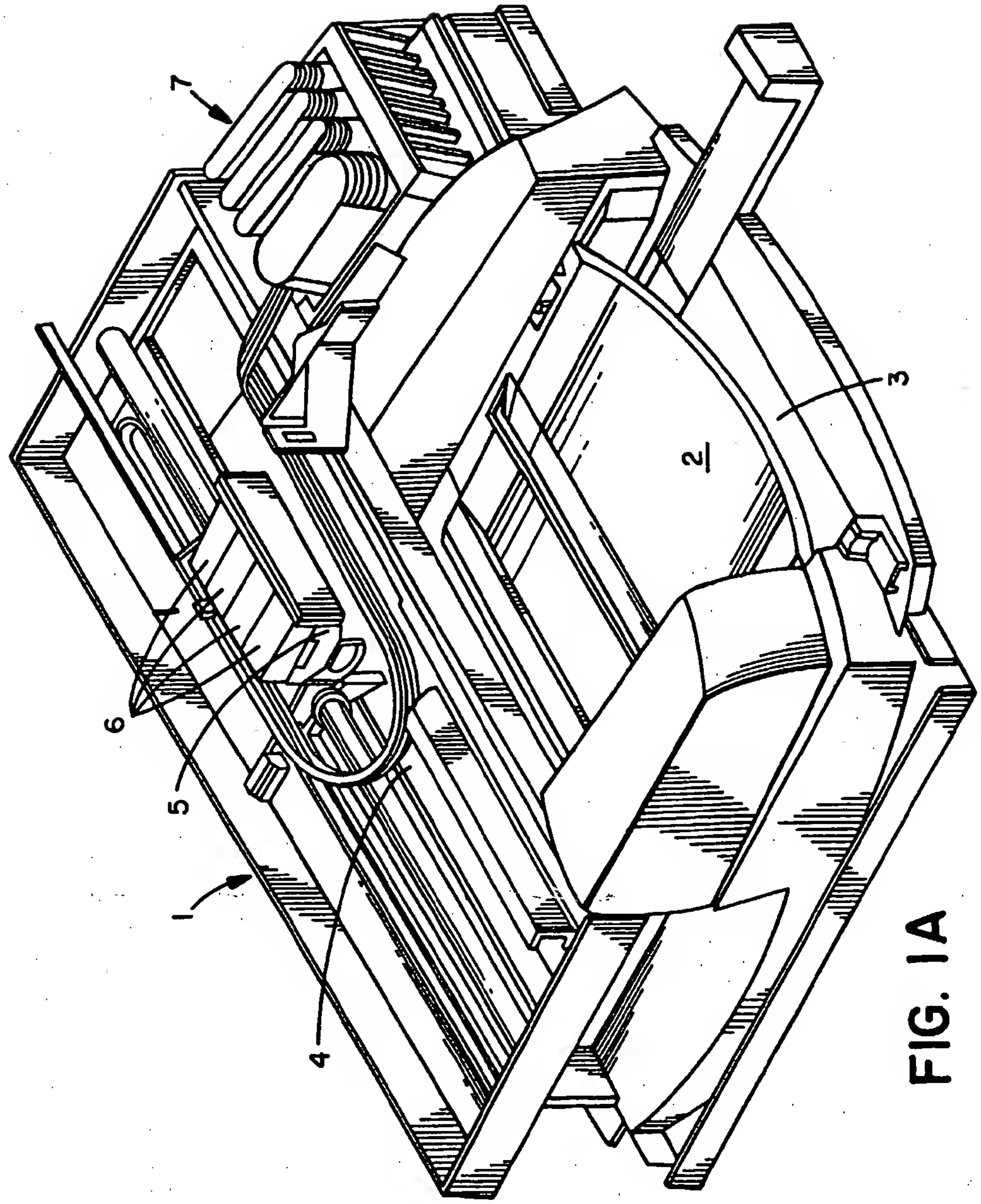


FIG. 1A

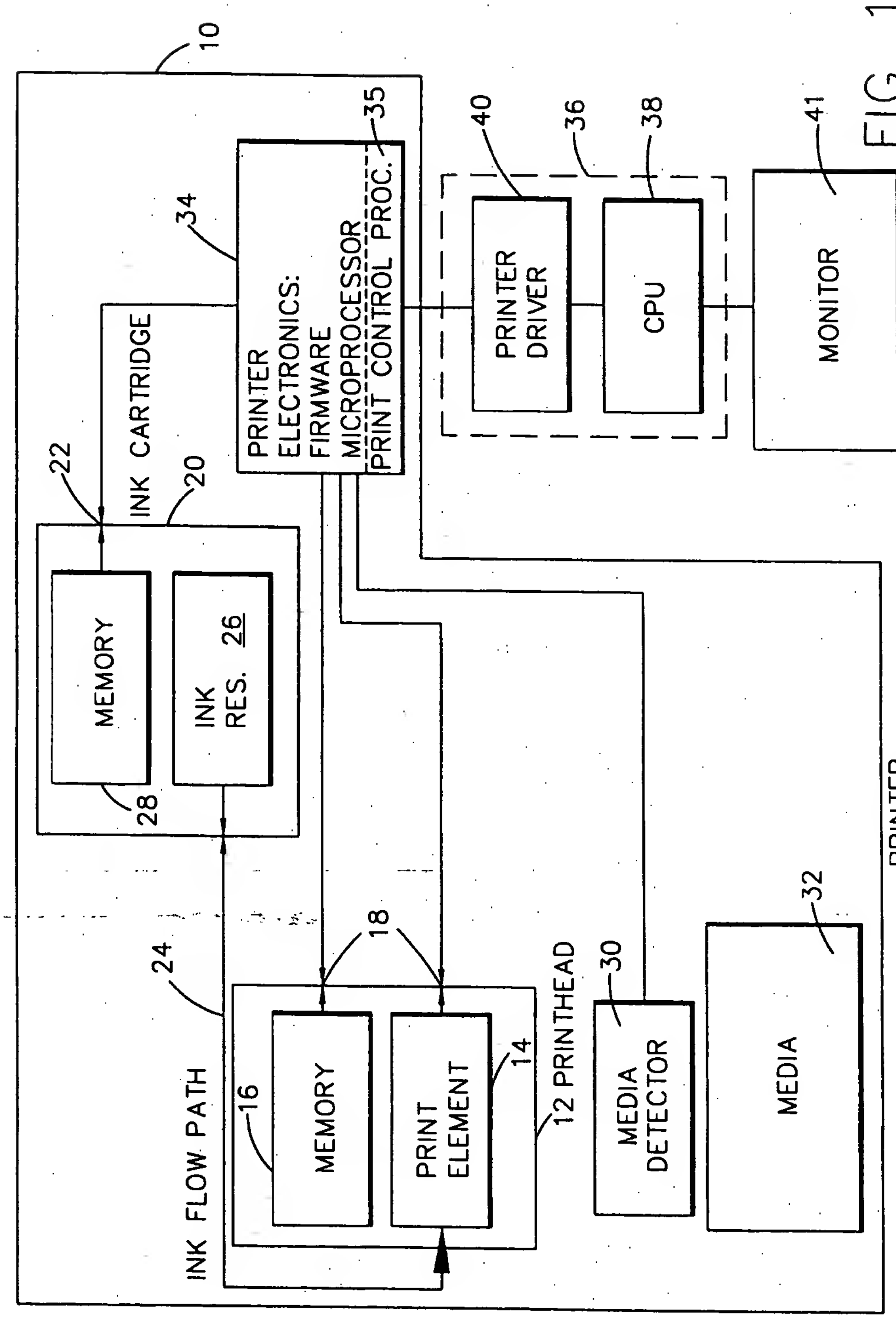

10
PRINTER ELECTRONICS: FIRMWARE MICROPROCESSOR
PRINT CONTROL PROC.
34
35
40
36
38
PRINTER DRIVER
CPU
41
MONITOR
22
INK CARTRIDGE
20
MEMORY
INK RES. 26
28
24
18
INK FLOW PATH
16
MEMORY
PRINT ELEMENT
14
12 PRINTHEAD
30
MEDIA DETECTOR
32
MEDIA
PRINTER

FIG. 1B

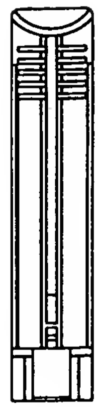


FIG.3

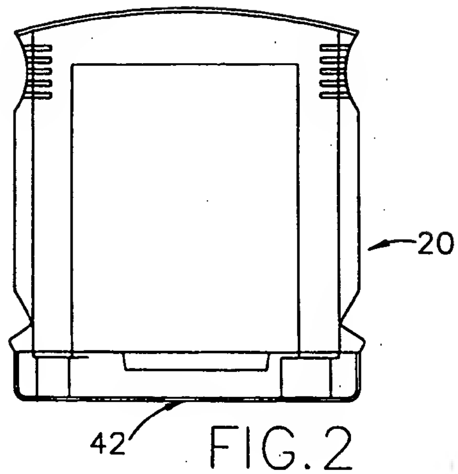


FIG.2

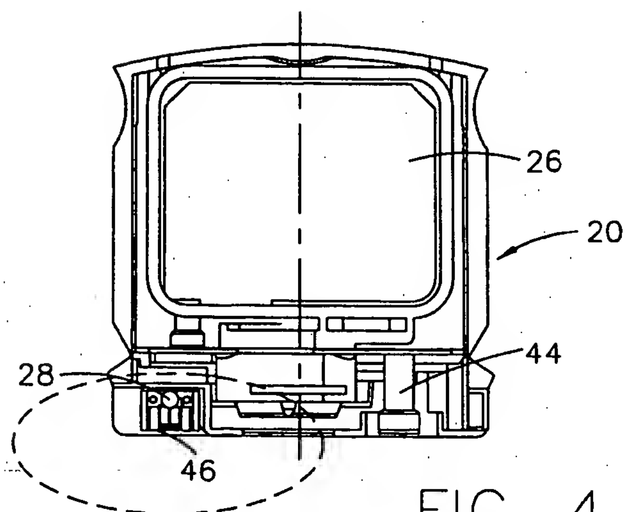


FIG. 4

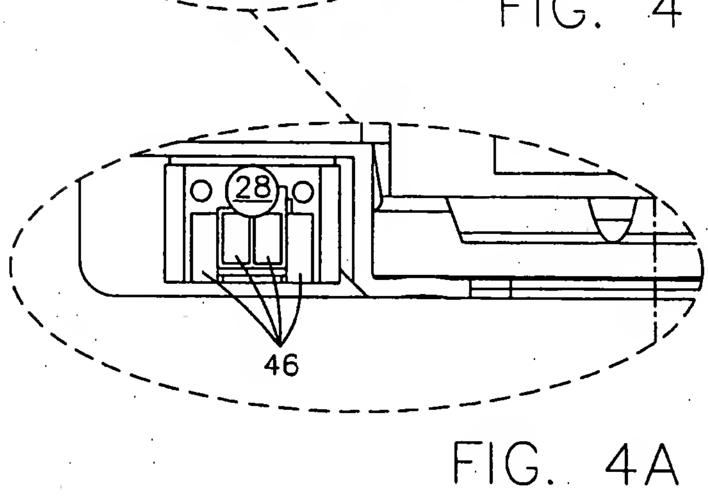


FIG. 4A

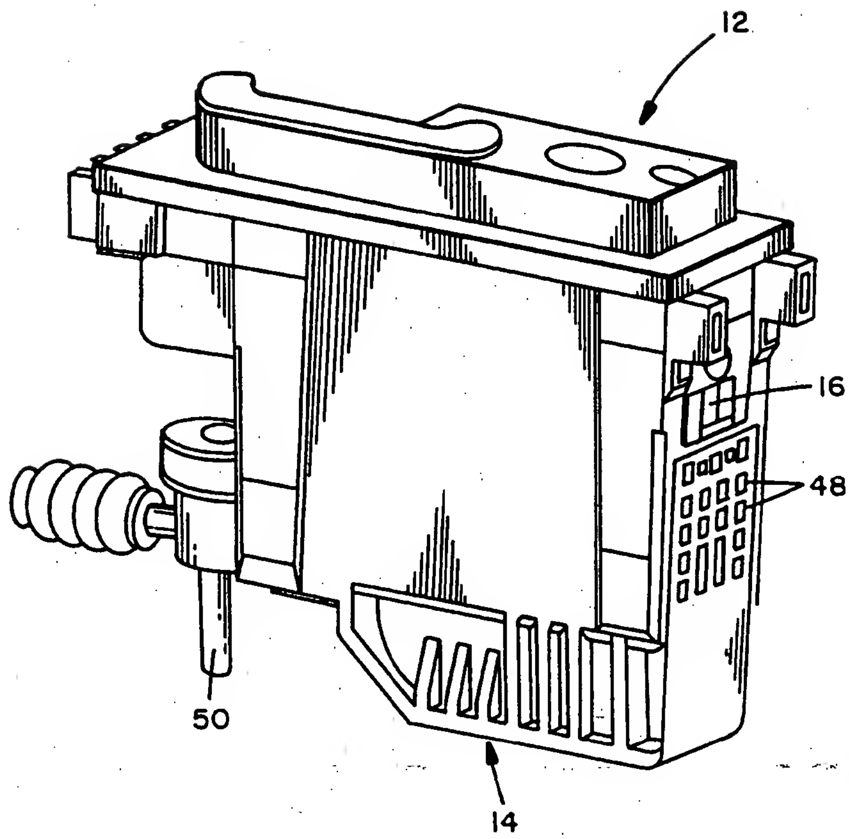
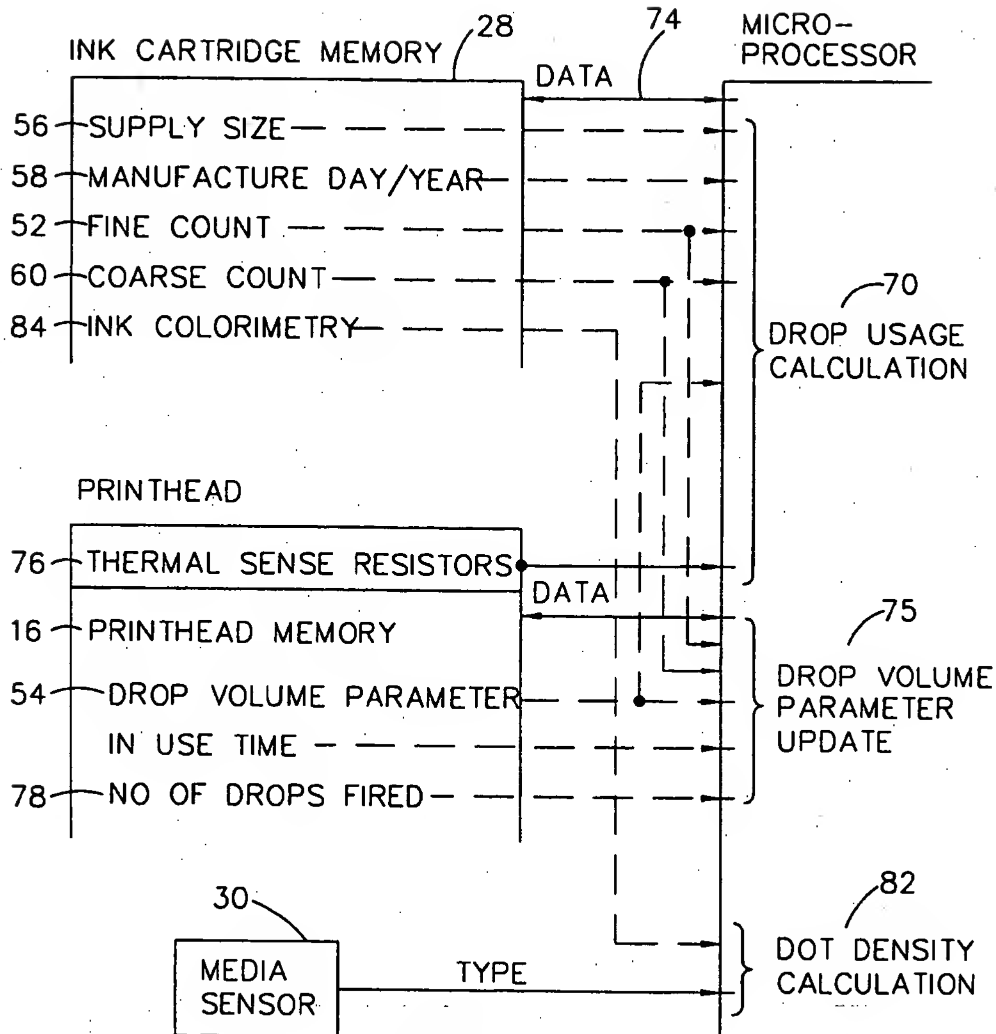
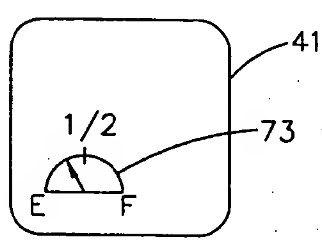


FIG. 5



INK CARTRIDGE MEMORY
28
74
DATA
MICRO-
PROCESSOR
56
SUPPLY SIZE
58
MANUFACTURE DAY/YEAR
52
FINE COUNT
60
COARSE COUNT
84
INK COLORIMETRY
70
DROP USAGE
CALCULATION
PRINTHEAD
76
THERMAL SENSE RESISTORS
DATA
16
PRINTHEAD MEMORY
75
54
DROP VOLUME PARAMETER
IN USE TIME
78
NO OF DROPS FIRED
DROP VOLUME
PARAMETER
UPDATE
30
82
MEDIA
SENSOR
TYPE
DOT DENSITY
CALCULATION

FIG. 6



41
1/2
73
E
F

FIG. 7